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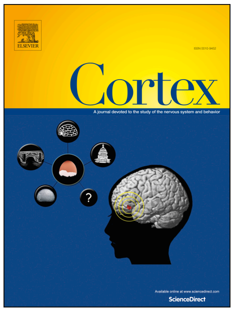

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Self-perspective inhibition deficits cannot be explained by general executive control difficulties

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Abstract

Understanding other people's point of view is crucial for successful social interaction but can be particularly challenging in situations where the other person's point view conflicts with our own view. Such situations require executive control processes that help us resist interference from our own perspective. In this study, we examined how domain-general these executive processes are. We report the performance of two pairs of brain-damaged patients who had sustained lesions in different areas of the prefrontal cortex and who showed deficits in classic executive function tasks. The patients were presented with desire reasoning tasks in which two sources of executive control were manipulated: the need to resist interference from one's own desire when inferring someone else's conflicting desire and the need to resist interference from the ascription of an approach motivation when inferring an avoidance-desire. The pattern of performance of the two pairs of patients conformed to a classic double dissociation with one pair of patients showing a deficit in resisting interference from their own perspective but not from the ascription of an approach motivation while the other pair of patients showed the opposite profile. The results are discussed in relation to the specificity of the processes recruited when we resist interference from our own perspective.

Keywords: perspective taking; desire reasoning; self-perspective inhibition; theory of mind; right inferior frontal gyrus

1. Introduction

Inferring what other people feel, think, want or intend to do is fundamental to make sense of their behaviours (Premack & Woodruff, 1978). One main source of difficulty when making these inferences is the need to resist interference from our own mental states when other people hold a different point of view. Failure to resist such interference leads to the well-documented egocentric biases in perspective taking (mentalising) tasks, which are found across the lifespan in healthy individuals (Birch & Bloom, 2004; Epley, Keysar, Van Boven, & Gilovich, 2004; Royzman, Baron, & Cassidy, 2003).

There is converging evidence that resisting interference from one's own mental states (hereafter referred to as "self-perspective inhibition") requires executive control. For example, recent findings have shown that children's ability to infer someone else's mental state is correlated with their abilities in classic executive function tasks especially when the other person holds a conflicting perspective (Fizke, Barthel, Peters, & Rakoczy, 2013; Rakoczy, 2010). It has also been shown that adults' egocentric biases are exacerbated when they are placed in dual task conditions, i.e. when less cognitive resources are available to overcome egocentric biases (Lin, Keysar, & Epley, 2010; Qureshi, Apperly, & Samson, 2010). Furthermore, a case has been reported of a patient with a selective deficit in self-perspective inhibition following acquired damage to the right lateral prefrontal cortex and this patient also showed deficits in classic executive function tasks (Samson, Apperly, & Humphreys, 2007; Samson, Apperly, Kathirgamanathan, & Humphreys, 2005). Finally, an fMRI study by van der Meer et al. (van der Meer, Groenewold, Nolen, Pijnenborg, & Aleman, 2011) showed substantial overlap between the brain areas involved in self-perspective inhibition and those involved in response inhibition outside the social domain (as measured by a stop-signal task). All this evidence suggests that the processes required to set our own point of view aside may not be specific to the social domain, but may be also involved in any other task that requires resisting interference from irrelevant and distracting information.

In this study we examined this issue by asking two questions: (1) do patients with a selective deficit in self-perspective inhibition have difficulties resisting interference from any salient and distracting information (other than their own perspective) when mentalising? And, (2) do patients with severe executive control difficulties necessarily have difficulties inhibiting their own perspective when mentalising?

Several studies have already investigated the issue of the co-occurrence of mentalising deficits and executive function deficits in brain-damaged patients. While the co-occurrence of both types of deficits is often reported, it is also usually stressed that the impairment in the mentalising tasks cannot solely be explained by executive function deficits (e.g., Bird, Castelli, Malik, Frith, & Husain, 2004; Blair & Cipolotti, 2000; Channon & Crawford, 2000; Fine, Lumsden, & Blair, 2001; Gregory et al., 2002; Lough & Hodges, 2002; Rowe, Bullock, Polkey, & Morris, 2001; for a review see Aboulafia-Brakha, Christe, Martory, & Annoni, 2011). However, there are two main limitations to the way the issue has been investigated so far. Firstly, most studies have not isolated within the mentalising tasks the self-perspective inhibition demands from other executive demands (such as holding information in working memory while processing the social scenario) and sometimes it is even unclear if the mentalising task requires self-perspective inhibition at all (such as in the case of the Reading the Mind in the Eyes test where participants are asked to identify the mental state expressed in a face while they themselves are in a neutral emotional state, Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997). It is thus unclear whether any relation assessed between the independent executive measures and the mentalising task speaks to the issue of self-perspective inhibition. Secondly, mentalising and executive function are always measured in independent tasks. This means that it is hard to control for differences in incidental task demands or for fluctuations in the availability of executive resources within or across testing sessions (Stuss, Murphy, Binns, & Alexander, 2003).

To overcome these limitations we presented our patients with newly designed mentalising tasks, more specifically desire reasoning tasks, in which we directly manipulated *within* the task the executive control demands related to self-perspective inhibition and the executive control demands related to the inhibition of other salient and distracting information, namely the ascription of an approach motivation when reasoning about avoidance desires.

Approach and avoidance are seen as the two classes of motives or drives to an action (Elliot, 2006). When children and adults reason about these two types of motives in order to predict someone else's action, it has been found that they are slower and make more errors when the other person wants to avoid something than when the other person wants to approach something (Apperly, Warren, Andrews, Grant, & Todd, 2011; Friedman & Leslie, 2004; German & Hehman, 2006). This is usually observed with objects that do not have an intrinsic positive or negative value, but where the context defines the other person's preferences. For example, in one of these studies (Apperly et al., 2011), participants were presented with a character in front of two boxes, each containing food, and were told that the character will open the box that contains the food he likes. When told that a specific food, for example an apple, was in one of the boxes, participants were slower to predict which box the character will open when previously told that the character did not like apples than when they previously told that he liked apples. This has been explained by the fact that reasoning about avoidance- compared to approach-desires requires additional inhibitory mechanisms in order to prevent a default approach motivation ascription and move attention away from the object to-be-avoided (Leslie, Friedman, & German, 2004; Leslie, German, & Polizzi, 2005).

Thus, reasoning about a conflicting perspective and reasoning about avoidance may both recruit executive processes to inhibit the prepotent response associated with the self-perspective and the approach motivation, respectively. However, it is currently unclear whether both types of inhibitory processes are the same. A recent study suggests that both types of processes may be sustained by both common and distinct brain areas (Hartwright, Apperly, & Hansen, 2012). In their study, Hartwright et al. used a belief-desire reasoning task in which participants were asked to predict which box a protagonist would open based on the protagonist's belief about an object location (consistent *versus* inconsistent with participants' own knowledge about the object location) and the protagonist's desire towards that object (he likes *versus* dislikes the object). They found greater anterior cingulate (as well as temporo-parietal junction) activation when participants had to process inconsistent perspectives and avoidance desires compared to consistent and approach desires, indicating that there are common processes when one needs to inhibit their own perspective and when one needs to inhibit the ascription of an approach desire. In addition, they also found distinct activation patterns across both types of inhibitory processes, with the processing of inconsistent perspectives but not avoidance reasoning recruiting the ventro-lateral prefrontal cortex. Hartwright et al.'s study thus laid the basis for the hypothesis that self-perspective inhibition processes are not necessarily entirely domain-general.

The current study reports the findings from two pairs of brain-damaged patients who show important deficits in classic executive function tasks but whose patterns of performance in desire reasoning tasks conform to a classic double dissociation, with one pair of patients showing a deficit in self-perspective inhibition but not in reasoning about avoidance while the other pair of patients shows the opposite profile. Quite strikingly, there was a substantial overlap when considering the lesions within each pair of patients but little overlap when considering the lesions across the two pairs of patients. The results are discussed in relation to the specificity of the executive processes involved in self-perspective inhibition.

2. Case reports

All four patients reported in this paper are part of a group of 20 patients who participated in several projects investigating the cognitive and neural basis of mentalising at the University of Birmingham. The data of 3 out of the 4 patients (patient SP only participated later) on false belief and intention reasoning tasks has been reported in previous publications (Apperly, Samson, Chiavarino, & Humphreys, 2004; Chiavarino, Apperly, & Humphreys, 2010; Samson et al., 2007, 2005). Patients were selected for the current study on the following basis. Patient WBA was previously identified as suffering from a selective impairment in self-perspective inhibition (Samson et al., 2005, 2007) and was thus core to the current project. Patient PW was the only patient within our sample who suffered similar lesions to the ones of WBA and was thus included in the study to test whether WBA's profile of performance would generalise to other patients with similar lesions. Ten patients (including WBA, PW, GA and SP) were presented with an initial desire reasoning task and patients GA and SP were the sole patients impaired in that task. In addition, both patients showed significant deficits in classic executive function tasks. They were thus selected for the current study in order to contrast more systematically their performance to that of WBA and PW.

The patients' T1 scans were transformed into the standard MNI space using SPM5 (Statistical Parametric Mapping, Welcome Department of Cognitive Neurology, London UK) by applying the advanced segment-normalize procedure according to Ashburner and Friston (2005) and were then submitted to a voxel-based morphometry (VBM) analysis in which the patients' segmented brain scans were compared to those of 201 control subjects through voxelwise t-tests controlling for effects of age, sex and handedness.

At the time of testing, patient WBA was 61. He is a right-handed lawyer who had suffered 5 years earlier a right hemisphere stroke leaving him with a left side weakness, some language problems (non-fluent speech and grammatical processing difficulties) as well as executive function difficulties. VBM analysis of the MRI data revealed signal intensity changes in the right inferior frontal gyrus (pars opercularis, triangularis and orbitalis), right insula, thalamus and caudate and right supramarginal, superior and middle temporal gyri.

Patient PW was, at the time of testing, a 75 year old retired florist. He was right-handed. Seven years prior to testing, PW suffered a right hemisphere stroke which led to a left upper limb hemiplegia as well as executive function difficulties. The VBM analysis revealed significant signal intensity anomalies in the right inferior frontal gyrus (operculum), right insula, putamen and caudate, right superior, middle and inferior temporal gyri and angular gyrus. Small signal intensity differences were also found in the left putamen and cerebellum bilaterally.

Patient GA was 52 when he participated in this study. He is right-handed and was a former professional musician. Fifteen years prior to testing GA contracted herpes simplex encephalitis leaving him with a severe amnesia, executive function difficulties and a category-specific agnosia for living things (see Humphreys & Riddoch, 2003; Sui & Humphreys, 2013). Significant signal intensity differences, as revealed by the VBM analysis, were found in the left and right anterior cingulate gyri, right parahippocampal gyrus and hippocampus, left hippocampus, right and left amygdala, right fusiform area, right and left insula, right caudate, and the right inferior and middle temporal gyri.

Patient SP was 53 at the time of testing. He is right-handed and a former bank manager. Like GA, he suffered from herpes simplex encephalitis (7 years prior to testing). He also showed a severe amnesia, executive function difficulties and a category-specific agnosia for living things. The VBM analysis showed significant differences in signal intensity in the right and left anterior cingulum, right inferior and superior orbital frontal, bilateral fusiform and parahippocampal extending into hippocampal gyri, right and left amygdala, insula and putamen, and the left mid occipital area.

Figure 1 shows the extent to which the patients' lesion sites overlapped (GA and SP in green; WBA and PW in red). Even though all four patients had quite widespread brain damage, there was comparatively little overlap across the lesions of the two pairs of patients: 92% of GA's and SP's common lesions did not overlap with WBA's and PW's common lesions and, 93% of WBA's and PW's common lesions did not overlap with GA's and SP's common lesions. The common lesioned area across all four patients mainly involved the following grey matter areas: the right inferior frontal gyrus (BA 47), right insula, right claustrum, right lentiform nucleus, right caudate, right extra-nuclear areas, right superior temporal gyrus (BA 38). Common abnormal white matter across all four patients were mainly found in the frontal, temporal and limbic areas. As far as differences are concerned across the two pairs of patients, GA and SP had more bilateral and medial fronto-temporal lesions whereas WBA and PW had right lateral fronto-temporal lesions. Furthermore, the lesions of GA and SP extended into the occipital lobe whereas the lesions of WBA and PW extended in the parietal lobe.

Table 1 summarises the patients' neuropsychological profile. As far as classic attentional and executive function tests are concerned, there was no striking difference across the two pairs of patients. Clinical features however showed that the two pairs of patients behaved differently during testing: GA and SP were extremely distractible while WBA and PW would show more thought perseverations.

Experiment 1 was also presented to 6 healthy age matched adults (all male, mean age = 62). All participants provided informed written consent prior to participating in this study.

[Insert Figure 1 and Table 1 about here]

3. Experiment 1

In Experiment 1, we presented the four patients as well as 6 control subjects with a desire reasoning task in which we manipulated two sources of executive control. First, we manipulated the need to inhibit one's own perspective by asking participants to reason about the approach desire of another person, contrasting situations where participants and the other person held the same desire (no need to inhibit one's own desire to make the correct judgement) with situations where participants and the other person held different desires (here the demands in self-perspective inhibition were high). Second, we manipulated the need to shift attention away from an object by asking participants to reason about their own desires and contrast situations where participants would want a certain item (no need to shift attention away from that object) with a situation where participants would not want that item (here the demands in inhibition were high). These manipulations were performed in the context of a card game played against a fictional opponent in which each player would either want a certain card to win money (approach desire) or would want to avoid a certain card to avoid losing money (avoidance desire). The details are reported below.

3.1. Methods

The card game was based on a design of game used with children (Moore, Jarrold, Russell, & Lumb, 1995) and involved two players (the participant and a fictional opponent). The game included two types of trials: winning and losing trials. On winning trials (cued with a sun symbol), one or both players could win a predetermined amount of money. On losing trials (cued with a cloud symbol), one or both players could lose a predetermined amount of money. On each trial, participants and their opponent would first receive a coloured card (either blue or red). A third card (blue or red) would then be presented and whoever had the same coloured card would win (on winning trials) or lose (on losing trials) the announced amount of money. For example, on a winning trial with 20 pounds at stake, if a player has received a blue card and the third deciding card is blue, he wins the 20 pounds but if the deciding card is red he does not win the money. On a losing trial with, for example, 50 pounds at stake, if a player receives a blue card and the third deciding card is blue, he loses 50 pounds while if the third deciding card is red, he does not lose any money. Before the colour of the third card was revealed, participants were asked to make desire judgements. More particularly, they were asked to judge either what they wanted the third card to be (self-perspective judgement) or what the opponent wanted the next card to be (other-perspective judgement). On winning trials, participants had to reason about approach desires (wanting the third card to be of the same colour as the card received) while on losing trials, participants had to reason about avoidance desires (not wanting the third card to be of the same colour as the card received).

For both approach– and avoidance–desire trials, on half of the trials, both the opponent and the participant had different coloured cards, thus each would want a different coloured card as outcome (different–perspective trials). On the other half of the trials, both parties had the same coloured card, and thus both would want the same coloured card as outcome (same–perspective trials). The judgement took the form of a verification task. This means that participants were shown a coloured card and were asked whether or not the colour matched the desire content that they were asked to judge (half of the time the correct response was "yes"). Note that our game structure allowed us to test the ascription of truly "conflicting" desires (incompatible desires about the same object, i.e. the third card) rather than the ascription of different but compatible desires (the latter being argued by some authors to be easier to process; e.g., Moore et al., 1995).

Each trial was thus characterised by the perspective to judge (self *versus* other), whether there was conflict between perspectives (conflict *versus* no conflict), whether the stake was to win or lose money (approach *versus* avoidance desire) and whether the prompt to verify matched the desire content or not (matching *versus* mismatching prompt, see Figure 2). Trials were equally distributed across all conditions (12 trials per condition) in order to avoid the use of superficial strategies to solve the task. This led to a total of 192 trials split across 4 blocks and preceded by a block of 20 practice trials. Trials were presented in pseudo-random order to avoid more than 3 consecutive trials of the same type.

The experiment was programmed with E-prime (Psychology Software Tools, 1996). Patients were comfortably seated 60 cm away from the screen. Each trial (see Figure 3) began with a fixation cross that remained on screen for 1000 ms followed by a 2000 ms displayed weather counter indicating whether it was a winning trial (sun symbol) or losing trial (cloud symbol) as well the amount of money at stake. After this cue, the patient would see two coloured cards simultaneously presented in the centre of the screen on the table. Two pictures, the participant and the opponent, were placed on each side of the table so that participants were always reminded which card was theirs. The two cards remained on the screen for 2000 ms and were followed by a 2000 ms perspective cue that indicated the perspective the patients needed to judge (“HE WANTS” or “YOU WANT”). Participants were specifically told in the instructions that the two cues corresponded to the following questions: “Which colour does Henry want the next card to be” or “Which colour do you want the next card to be?”. Then a single coloured card (blue or red) prompt would appear, and participants were asked to accept or reject the proposed desire content. The coloured card remained visible until participants gave their response. Patients responded by pressing one of two keys of the numeric pad of the keyboard: “1” if the card matched the desire content and “4” if the card did not match the desire content. Stickers were used on the keyboard to remind which key to press: “yes” (=1) and “no” (=4). After patients made their response, a final frame depicting the actual identity of the third card and the outcome of the trial (i.e. who won or lost money) was displayed. This frame was controlled by the examiner who also controlled the onset of the next trial by pressing the spacebar. This was done to ensure that patients were fully attending to the task before the next trial would be presented.

[Insert Figures 2 and 3 about here]

We only analysed trials that provide a “pure” measure of self-perspective inhibition and those that provide a “pure” measure of inhibition of the card to be avoided (see Figure 2). For the self-perspective inhibition measure, we considered the other-perspective and approach trials, contrasting trials in which (i) there was a conflict between the self- and the other-perspective because both received a different coloured card at the beginning of the trial (high self-perspective inhibition demand condition, collapsing matching and mistmaching trials, n=24) and (ii) there was no conflict between the self- and the other-perspective because both received the same coloured card at the beginning of the trial (low self-perspective inhibition demand condition, collapsing matching and mismatching trials, n=24). By considering only the approach trials, we could measure the self-perspective inhibition cost uncontaminated by the cost related to avoidance reasoning.

For the inhibition of the card to be avoided, we considered the self-perspective and same perspective trials, contrasting trials with (i) avoidance desires (high demands in shifting attention away from the first card received, collapsing matching and mismatching trials, n=24) and those with (ii) approach trials (no need to shift attention away from the first card received, collapsing matching and mismatching trials, n=24). By considering only the self-perspective trials, we could measure the avoidance reasoning cost uncontaminated by the cost related to self-perspective inhibition.

These two pure measures were chosen to clearly separate the origin of the executive demands (both sources of executive control being indissociable on avoidance/other-perspective trials). Only accuracy data were taken into account for the patients and the control participants.

3.2. Results

3.2.1. Self-perspective inhibition. As far as self-perspective inhibition is concerned (see Figure 4, upper panel), patients WBA and PW performed worse on the trials where their own perspective conflicted with that of the other person than on the trials where there was no conflict. These discrepancies between trials with and without conflicting perspectives were significantly different from the discrepancies observed in the control participants (Revised Standardized Difference Test, Crawford & Garthwaite, 2005; for patient WBA, $t(5)= 6.395$, p(two-tailed)=0.001; for patient PW, $t(5)= 3.560$, p(two-tailed)=0.016). Furthermore, both WBA and PW showed a deficit for conflict trials compared to controls (Crawford & Howell, 1998's test; for patient WBA, $t(5)=-2.945$, p(one-tailed) = 0.016; for patient PW, $t(5)=-2.415$, p(one-tailed) = 0.030) but no deficit for no conflict trials (for patient WBA, $t(5)=0.229$, p(one-tailed) = 0.414; for patient PW, $t(5)=-0.993$; p(one-tailed) = 0.183).

In contrast, patients GA and SP showed no such discrepancies between their performance on conflict and no conflict trials, and their level of discrepancy was similar to that of control participants (Revised Standardized Difference Test, Crawford & Garthwaite, 2005; for patient GA, $t(5)= 0.354$, p(two-tailed)=0.738; for patient SP, $t(5)= 0.223$, p(two-tailed)=0.832). Furthermore, neither of the two patients showed a deficit compared to controls in the conflict or the no conflict trials (Crawford & Howell, 1998's test; for patient GA and conflict trials, $t(5)=0.412$, p(one-tailed) = 0.349; for patient GA and no conflict trials, $t(5)=0.535$, p(one-tailed) = 0.308; for patient SP and conflict trials, $t(5)=-0.765$; p(one-tailed) = 0.239; for patient SP and no conflict trials, $t(5)=-0.687$; p(one-tailed) = 0.261). Thus, the profile of WBA and PW did fulfil the criteria for a classical dissociation between the low and high self-perspective inhibition demand conditions while no dissociation (either classical or strong; Crawford, Garthwaite, & Gray, 2003) was observed for GA and SP.

Finally, we directly compared the patients on the condition most demanding in terms of self-perspective inhibition (i.e., the trials in which there was a conflict between perspectives) using the Bayesian inferential methods for comparing the scores of two single-cases in case-controls designs (Crawford, Garthwaite, & Wood, 2010). Patients WBA and PW did not differ one from another (p(two-tailed) = 0.7023) nor did patients GA and SP differ one from another (p(two-tailed) = 0.798). However, both WBA and PW performed significantly worse than patients GA and SP (WBA vs. GA: p (one-tailed) = 0.025; WBA vs. SP: p (one-tailed) = 0.018; PW vs. GA: p (one-tailed) = 0.041; PW vs. SP: p (one-tailed) = 0.030).

3.2.2. Approach-desire inhibition. As far as the inhibition of the ascription of an approach motivation is concerned (see Figure 4, lower panel), patient WBA performed worse for avoidance than approach trials and this discrepancy was significantly larger than the one found in the control participants (Test by Crawford & Garthwaite, 2005; t(5)= 3.363, p(two-tailed)=0.022). However, his performance on either type of trial was not significantly different to the performance of the control subjects (Test by Crawford & Howell, 1998; for avoidance trials, t(5)=1.352, p(one-tailed) = 0.117; for approach trials, t(5)=0.618, p(one-tailed) = 0.282). Patient PW, on the other hand, showed no discrepancy between avoidance and approach trials and the level of discrepancy was similar to that of control participants (Test by Crawford & Garthwaite, 2005; for patient PW, t(5)= 0.952, p(two-tailed)=0.385). However, he showed a marginal deficit for avoidance trials compared to controls but no deficit for approach trials (Test by Crawford & Howell, 1998; for patient PW and avoidance trials, t(5)=1.875, p(one-tailed) = 0.059; for patient PW and approach trials, t(5)=1.376, p(one-tailed) = 0.114).

In contrast, patients GA and SP both showed a much clearer cut difference in their performance on avoidance compared to approach trials and this discrepancy was significantly larger than that found in the control group (Test by Crawford & Garthwaite, 2005; for patient GA, t(5)= 6.537, p(two-tailed)=0.001; for patient SP, t(5)= 6.768, p(two-tailed)=0.001). Furthermore, both patients showed a marked deficit for avoidance but not for approach trials compared to controls (Test by Crawford & Howell, 1998; for patient GA and avoidance trials, t(5)=4.229, p(one-tailed) = 0.004; for patient GA and approach trials, t(5)=0.618, p(one-tailed) = 0.282; for patient SP and avoidance trials, t(5)=4.490; p(one-tailed) = 0.003; for patient SP and approach trials, t(5)=0.618; p(one-tailed) = 0.282). Thus here, the profile of GA and SP fulfilled the criteria for a classical dissociation between approach and avoidance reasoning demand conditions while no dissociation (either classical or strong; Crawford et al., 2003) was observed for WBA and PW.

A direct comparison of the patients' performance on the avoidance-desire trials was conducted using the Bayesian inferential methods for comparing the scores of two single-cases in case-controls designs (Crawford et al., 2010). This showed that there was no significant difference between patients WBA and PW (p(two-tailed) = 0.706) or between patients GA and SP (p(two-tailed) = 0.850). However, patients GA and SP performed significantly worse than patients WBA and PW (although for the comparison with PW the difference was only marginally significant; GA vs. WBA: p (one-tailed) = 0.040; GA vs. PW: p (one-tailed) = 0.066; SP vs. WBA: p (one-tailed) = 0.031; SP vs. PW: p (one-tailed) = 0.051).

[Insert Figure 4 about here]

3.3. Discussion

Patients WBA and PW were hypothesized to have a selective deficit in self–perspective inhibition. In line with this hypothesis, both patients made significantly more errors when reasoning about another person's approach-desire if their own desire conflicted with that of the other person. Patient WBA also showed difficulties resisting interference from the ascription of an approach-desire when reasoning about avoidance, but these difficulties were reliably smaller then for GA and SP. Patient PW, on the other hand, showed no significant impairment in his ability to reason about avoidance–desires. Thus, both WBA and PW showed a disproportionate deficit in inhibiting their own perspective compared to their ability to inhibit the ascription of an approach motivation.

In contrast, patients GA and SP showed the opposite profile. They performed significantly worse when required to make avoidance–desire responses compared to approach responses. However, neither patient had any difficulty in resisting interference from their own desire when judging someone else's approach desire, showing thus no signs of self–perspective inhibition deficit.

Are the deficits shown by the four patients executive in nature or do they reflect a conceptual deficit? It could be argued that the patients did not understand the task instruction or, for example, that GA and SP lost the concept of "avoidance". To assess the executive nature of the deficits, we presented the patients with variations of Experiment 1 specifically designed to increase and decrease the salience of the information to be inhibited. In Experiment 2, we contrasted a condition in which the salience of the self-perspective was decreased by having WBA and PW only focus on the other person's perspective and never judge their own perspective (Experiment 2a) with a condition in which self- and other-perspective judgments were mixed (Experiment 2b). This latter "shifting" condition is similar to Experiment 1 and should lead WBA and PW to make errors when judging the other person's perspective when that perspective conflicts with their own perspective. If the origin of the deficit is executive in nature, then we should predict that the error rate will decrease in Experiment 2a. However if the patients' deficit is conceptual, for example, if they cannot understand that someone else could have a different perspective, then the patients should have similar levels of difficulties in both Experiment 2a and 2b.

Experiment 3 was based on the same rationale. In Experiment 3a, GA and SP were asked to make judgements about their own avoidance desire only. In contrast, in Experiment 3b, the patients were asked to switch between self approach- and self avoidance-desire judgements. In the former case, the salience of the dominant and easier judgement (approach judgement) was reduced by making this judgement never relevant to the task and thus easier to resist interference from when making an avoidance judgement. If the origin of GA's and SP's deficit is executive in nature, the patients should make fewer errors in Experiment 3a compared to Experiment 3b. On the other hand, if both patients have a conceptual deficit and do not understand the concept of avoidance anymore, then they should have similar levels of difficulties in both Experiment 3a and 3b.

4. Experiment 2: High vs. Low self-perspective inhibition demands

4.1. Methods

Patients WBA and PW were presented with two tasks based on the same game as in Experiment 1. There were a few changes in the visual setting of the game (Figure 5). First, the sequence of events was presented more dynamically within an animation clip (programmed with Adobe Flash Professional 8). The opponent was sitting at a table facing the participant and moved his eyes towards the cards on the table and towards the camera to look at participants. This was done to enhance the salience of the opponent. There was also an additional character, namely a card dealer, who distributed the cards and turned over the third card. Secondly, there were three instead of two possible coloured cards (yellow, red and blue).

As in Experiment 1, each trial began with the display of the weather counter, indicating whether the stake was to win (sun symbol) or lose money (cloud symbol). The card dealer would then distribute the cards, always starting with the participant. Each card was visible for 500 ms before being turned over. The video was paused before the card dealer turned the third deciding card of that particular trial and patients were asked the test question. Similarly to Experiment 1, the test question asked participants either which colour they wanted the third card to be (self-perspective judgement) or which colour the opponent wanted the third card to be (other-perspective judgement). In contrast to Experiment 1, however, the question was open and participants had to name the colour corresponding to the desire content (instead of a verification task). Once a response was given, the examiner pressed a button to continue the animation which revealed the colour of the third card. The winner or loser of that trial was declared and the scoreboards on the screen were updated accordingly.

Crucially, in Experiment 2a, participants were only asked to judge the opponent's desire throughout the task (reduced executive demand condition) while in Experiment 2b, self- and other-perspective trials were mixed within the task.

In Experiment 2a, there was a total of 48 trials split evenly across Desire Type (Approach versus Avoidance) and Perspective Conflict (Conflict versus No Conflict between participants' and their opponent's desires). In Experiment 2b, there was a total of 96 trials split evenly across Desire Type (Approach versus Avoidance), Perspective Conflict (Conflict versus No Conflict between participants' and their opponent's desires) and Perspective (Self- versus Other-perspective judgement). In both experiments, only approach-desire trials were analysed.

[Insert Figure 5 about here]

4.2. Results

In Experiment 2a, when only asked to take the other person's perspective, both WBA and PW performed at ceiling (see Figure 6). However, in Experiment 2b where self- and other-perspective trials were mixed, both patients responded mostly according to their own perspective, leading to a close to ceiling performance when judging their own desire, a performance at ceiling when judging the opponent's desire on trials where his desire was the same as theirs, but many mistakes when judging the opponent's desires when their own desire was different to the desire of their opponent. In that latter case, the number of correct responses of WBA was not significantly different from chance (Binomial test, with a probability to guess the correct response of 0.5, p (one-tailed) = 0.39) and, the number of correct responses of PW was even significantly below chance level (Binomial test, p (one-tailed) < 0.01).

4.3. Discussion

Both WBA and PW were perfectly able to take the opponent's perspective when the demands in self-perspective inhibition were reduced by making self-perspective judgements irrelevant to the task. However, when mixing self- and other-perspective judgements and thereby enhancing the salience and relevance of the self-perspective, both patients' number of correct responses significantly dropped when they had to judge the opponent's conflicting perspective. This clearly indicates that the origin of the difficulty is executive rather than conceptual in nature.

5. Experiment 3: High vs. Low approach-desire inhibition demands

5.1. Methods

The same visual set-up as in Experiment 2 was used here. In Experiment 3a, GA and SP were only asked to make self-perspective avoidance judgements, with 12 trials in which the opponent player had the same card as the participants (no perspective conflict) and 12 trials in which the opponent player had a different card than the participant (perspective conflict). In Experiment 3b, the patients were again asked to only judge their own perspective but this time avoidance judgement trials (12 trials with perspective conflict; 12 trials without perspective conflict) were mixed with approach judgement trials (12 trials with perspective conflict; 12 trials without perspective conflict).

During the game, the examiner asked the patients to report and tell her what the rules of the game were and what each symbol represented. This occurred at the beginning, half way through the task and at the end upon completion of the task. This precaution was taken because of GA and SP's severe amnesia.

5.2. Results

In Experiment 3a, when only making avoidance desire judgements, SP performed at ceiling and GA's number of correct responses was above chance level (Binomial test, with a probability to guess the correct response of 0.66, p (one-tailed) > 0.17). However, in Experiment 3b when avoidance desire judgements were mixed with approach desire judgements, both patients responded mostly by ascribing an approach motivation. This led to correct responses on approach desire trials but led, for avoidance desire judgements, to a number of correct responses that was significantly below chance level for both patients (Binomial test, with a probability to guess the correct response of 0.66, p (one-tailed) < 0.01). Importantly, both patients were able to report the rules of the game at the beginning, middle and upon termination of the task.

5.3. Discussion

Both GA and SP were perfectly able to reason about avoidance when the demands in inhibiting the approach motivation were reduced by making approach desire judgements irrelevant to the task. However, when mixing approach and avoidance judgements and thereby enhancing the salience and relevance of approach motivations, the number of correct responses significantly dropped for both patients when they had to judge their own avoidance desire. Importantly, this could not be explained by the patients forgetting the task instructions because both patients were perfectly able to recall the task instructions when prompted to do so. Thus, similarly to WBA and PW, this clearly indicates that the origin of the difficulty is executive rather than conceptual in nature.

6. General Discussion

The current study aimed at examining the link between self-perspective inhibition and more general executive control abilities. To address this issue we compared the performance of two pairs of patients. One pair consisted of patient WBA, previously known to show a deficit in self-perspective inhibition (Samson et al., 2007, 2005) and patient PW whose lesions were in similar brain areas to those in WBA (including in the right lateral prefrontal cortex). The second pair of patients, GA and SP, showed similar executive function deficits in classic neuropsychological tests as WBA and PW but their lesions encompassed different brain areas to those of WBA and PW (including bilateral ventral and medial prefrontal areas). Across a set of three experiments we demonstrated that the behavioural profile of these two pairs of patients in desire reasoning conforms to a classic double dissociation, with one pair of patients, WBA and PW, being sensitive to the executive demands in terms of self-perspective inhibition, and another pair of patients, GA and SP, sensitive to the executive demands in terms of inhibiting the ascription of an approach motivation. Thus, the results show that (1) patients with a selective deficit in self-perspective inhibition (like patients WBA and PW) do not necessarily have difficulties resisting interference from any salient and distracting information other than their own perspective when mentalising since they can resist interference from the (possibly default) ascription of an approach motivation and (2) patients with severe executive control difficulties do not all necessarily have difficulties inhibiting their own perspective when mentalising as shown by the performance of patients GA and SP.

For all four patients we demonstrated that the origin of the deficit was executive rather than conceptual in nature. Indeed, the deficit of WBA and PW took the form of difficulties imputing a correct desire to someone else when the other person held a conflicting desire but only when the patients' own desire was made very salient (Experiment 1 and 2b). In contrast, when the patients' own desires was made less salient (by never asking to reflect on their own desire during the task, Experiment 2a), then both patients were perfectly able to impute a conflicting desire to someone else. Thus, they both showed an understanding that someone else's desire is not necessarily the same as one's own desire, but they could not use that knowledge to correctly infer the other person's desire when their own desire was too salient.

The deficit exhibited by GA and SP took the form of difficulties imputing an avoidance desire to themselves but only when an approach motivation was made very salient

(Experiment 1 and 3b). In contrast, when the approach motivation was made less salient (by never asking the patients to reflect on approach desires, Experiment 3a), then both patients were perfectly able to impute an avoidance desire to themselves. We also ruled out that the difficulty shown by GA and SP were due to their amnesia since both patients were perfectly able to recall the rules of the task before, during and just after completing the task. Thus, GA and SP perfectly understood the concept of avoidance and the task instruction but were unable to impute an avoidance desire when there was a strong competition to ascribe an approach desire.

Interestingly, the double dissociation indicates that one source of executive control was not intrinsically easier than the other. Furthermore, in Experiment 1 both sources of executive control were manipulated within the same task and within the same testing session. The double dissociation can thus not be explained by a fluctuation in the patients' availability of executive resources (Stuss et al., 2003). Finally, all patients showed a similar extent of difficulties on classic executive function tests (especially when considering WBA, PW and GA who seemed more impaired than SP). Thus, there is no simple way to explain the patients' pattern of performance in relation to the severity of their executive function deficits. Instead, the data suggest that self-perspective inhibition and the inhibition of an approach motivation are at least partially distinct sources of executive control in desire reasoning and each can be selectively affected following acquired brain damage.

Our results are in line with previous behavioural findings showing that healthy children and adults are sensitive to both sources of executive control (Apperly et al., 2011; Friedman & Leslie, 2004; German & Hehman, 2006). Our findings are also consistent with a previous fMRI study showing that both types of executive control activate common but also *distinct* brain areas, with the most inferior parts of the vlPFC being more specifically modulated by the self-perspective inhibition demands (Hartwright et al., 2012). Interestingly, one cluster in the right PFC within these specific areas shown by Hartwright et al. (2012) overlapped with the common lesioned areas in patients WBA and PW but not the common lesioned areas in patients GA and SP (see Figure 7a). This region was also close to areas in the right inferior frontal gyrus found to be specifically activated in three other fMRI studies when there was a conflict between participants' own and someone else's perspective (Abraham, Rakoczy, Werning, von Cramon, & Schubotz, 2010; van der Meer et al., 2011; Vogeley et al., 2001), and here again, the overlap was with the common lesions in WBA and PW but not the common lesions in patients GA and SP (see Figure 7b,c,d,e). In these previous fMRI studies, self-perspective inhibition was most often measured in belief reasoning tasks in which participants' knowledge of the true state of affairs conflicted with another person's false belief about the state of affairs (Abraham et al., 2010; Hartwright et al., 2012; van der Meer et al., 2011). In the current study we used a desire reasoning task, corroborating the earlier finding from WBA that common self-perspective inhibition processes are involved irrespective of the type of mental state (belief, desire, perception) these processes operate on (Samson et al., 2005).

The right inferior frontal gyrus has been associated with the inhibition of responses and task-sets in non-social tasks (Aron, Robbins, & Poldrack, 2004; Konishi et al., 1999; Konishi, Nakajima, Uchida, Sekihara, & Miyashita, 1998). Furthermore, van der Meer et al. (2011) found substantial overlap within the left and right inferior frontal gyrus between brain activation associated with self-perspective inhibition and brain activation in a stop-signal task. Such findings suggest that there may be common processes across self-perspective inhibition and other forms of inhibitory control. However, the fact that patients WBA and PW had less or no difficulties inhibiting other salient and irrelevant information (such as the ascription of an approach motivation) highlights that there are also distinct processes related to self-perspective inhibition. This is not to say, however, that self-perspective inhibition processes are necessarily and entirely specific to perspective taking. Further studies are thus needed to find the relevant dimension that defines the boundary of operation of these inhibitory processes.

Areas specific to the executive control demands linked to avoidance reasoning are more difficult to extract from previous fMRI studies as the previously used designs have measured the ability to ascribe an avoidance desire to someone else (Hartwright et al., 2012; Hartwright, Apperly, & Hansen, 2014). Avoidance reasoning processes were thus confounded with other-perspective taking processes. Our design is unique in this respect as it assesses avoidance reasoning on self-perspective judgements. The fact that GA and SP had selective deficits in resisting interference from the ascription of an approach motivation but no deficit in resisting interference from their own desire suggests that the inhibition of an approach motivation relies on processes that are at least partially functionally and neurally distinct to the processes involved in self-perspective inhibition. It is important to note that in our study, approach and avoidance motivations were manipulated in the context of a task in which the reward associated to a stimulus was not intrinsic to the stimulus but learned and changing as a function of task-instructions (e.g., having a third card of the same colour as the card initially received was good on winning trials but bad on losing trials). The processes of approach-desire inhibition which seem to be impaired in patients GA and SP may be specific to these more complex and higher-order associations between reward and stimulus identity.

Finally, it is important to note that, although we refer to the cognitive processes impaired in the four patients as “inhibition” processes, our data do not speak to the issue of how these processes are implemented in the brain, i.e. whether it consists of down regulating the processing of the irrelevant information, up regulating the processing of the relevant information or both (Aron et al., 2004; Aron, 2007; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003). Our data suggest however that the control operations regulating the information related to the self *versus* the other are at least partially segregated at the neural level from the control operations regulating approach *versus* avoidance motivation ascription.

7. Conclusion

Overall, the pattern of performance reported in this study strongly suggests that patients with a self-perspective inhibition deficit do not necessarily have difficulties resisting interference from any other salient but irrelevant information (such as an approach motivation) when mentalising. Furthermore, our data also show that not any patient with severe executive function deficits will show a self-perspective inhibition deficit when mentalising. This highlights the need to further delineate at the functional and neural level the processes associated with self-perspective inhibition.

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Figure Captions

Figure 1. Overlapping lesion areas in GA and SP (green), WBA and PW (red) and across all four patients (yellow).

Figure 2. Illustration of the experimental design of Experiment 1 crossing orthogonally the type of desire to judge (approach or avoidance), the perspective to judge (self or other), the conflict between perspectives (conflict or no conflict) and the prompt to verify (matching or mismatching). Full bordered conditions are those considered for the pure measure of self-perspective inhibition (conflicting compared to same perspectives) and dashed bordered conditions are those considered for the pure measure of approach motivation inhibition (avoidance compared to approach-desire).

Figure 3. Illustration of the sequence of events within a trial in Experiment 1.

Figure 4. Number of correct responses in Experiment 1 for the four patients and the controls in the conditions contrasting the demands in terms of self-perspective inhibition (upper panel) and avoidance reasoning demands (lower panel).

Figure 5. Illustration of the visual set-up of Experiments 2 and 3.

Figure 6. Number of correct responses when the executive demands in terms of self-perspective inhibition were manipulated for WBA and PW (upper panel) and when the executive demands in terms of avoidance reasoning were manipulated for GA and SP (lower panel).

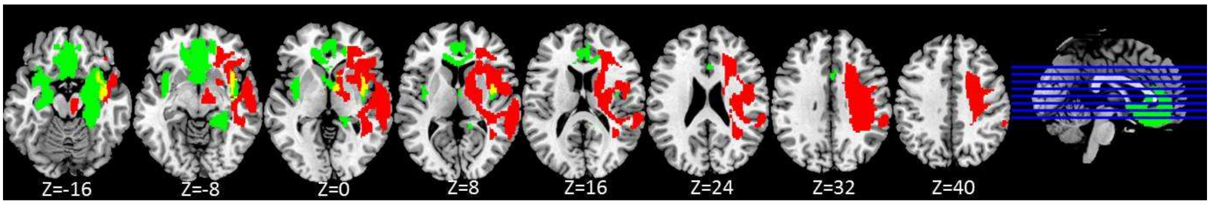
Figure 7. Overlap between the patients' lesions (Green: common lesions of GA and SP; red: common lesions of WBA and PW; yellow: common lesions across all patients) and the peak foci of activation (MNI coordinates) in the right inferior frontal gyrus linked to self-perspective inhibition reported in a) Hartwright et al. (2012), b) Vogeley et al. (2001), c) Abraham et al. (2010), e) and f) van der Meer et al. (2011).

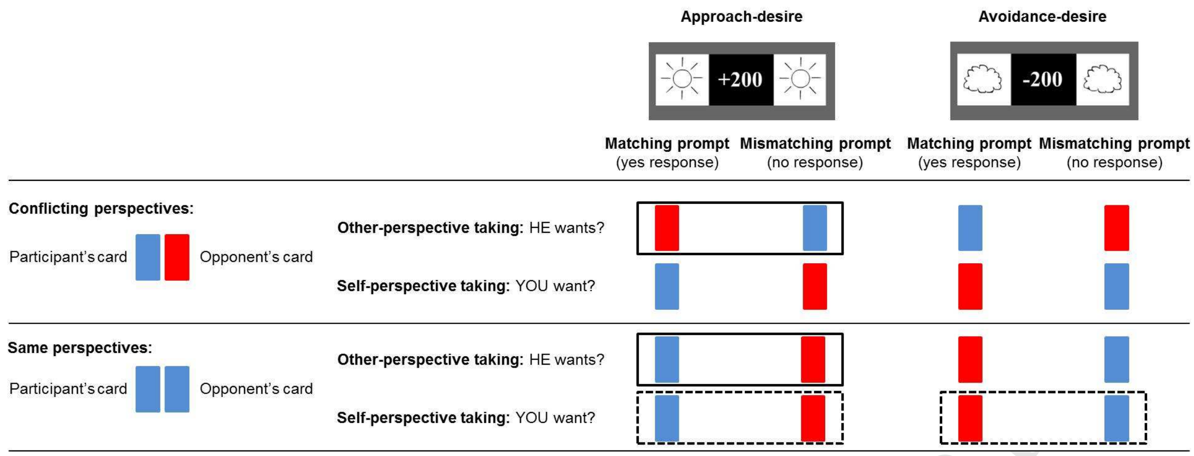
Table 1. Neuropsychological profile of the four patients.

	WBA	PW	GA	SP
Language				
BCoS Picture naminga – % correct (Percentile)	86% (>P5)	93% (>P5)	7% (<P5)	NT
Animal fluency[b] – number of words in 1 minute (Percentile)	24 (P50-75)	20 (P75-90)	**13 (<P10)**	**9 (<P10)**
Working memory				
Digit span[c] (Z-score)	5 (-2.02)	4 (-2.91)	5 (-2.03)	7 (-0.27)
Digit manipulation[c] – % correct (Z-score)	**79% (-5.76)**	**86% (-3.71)**	**81% (-5.14)**	100% (0.38)
Digit maintaining during interference[c] – % correct (Z-score)	90% (0.80)	47% (-1.04)	44% (-1.19)	65% (-0.28)
Digit updating[c] – % correct (Z-score)	**67% (-2.20)**	86% (-0.02)	85% (-0.10)	83% (-0.33)
Long-term memory				
BCoS Story immediate free recall[d] – % words (Percentile)	80% (>P5)	60% (>P5)	**37% (<P5)**	NT
BCoS Story immediate free recall + recognition[d] – % words (Percentile)	100% (>P5)	93% (>P5)	**60% (<P5)**	NT
BCoS Story delayed free recall + recognition[d] – % words (Percentile)	97% (>P5)	77% (>P5)	**7% (<P5)**	NT
BCoS Story delayed free recall + recognition[d] – % words (Percentile)	100% (>P5)	100% (>P5)	**27% (<P5)**	NT
WRM[e] – % words (Z-score)	NT	NT	**48% (-6.26)**	**62% (-4.21)**
WRM[e] – % faces (Z-score)	NT	NT	**62% (-3.8)**	**66% (-3.23)**
Attention and Executive function				
Selective attention: D2 – speed: total number of signs processed[f] (Percentile)	339 (P38)	NT	567 (P99)	358 (P38)
Selective attention: D2[f] – quality: % omissions + false alarms (Percentile)	7% (P50)	NT	**28% (<P1)**	6% (P50-75)
Inhibition: stimulus selection RT cost[g] (Z-score)	**1.96 (-5.30)**	0.98 (-1.82)	**1.89 (-5.05)**	**1.91 (-5.13)**
Inhibition: stimulus selection accuracy cost[g] (Z-score)	**0.25 (-2.26)**	0 (0.32)	**1.19 (-11.97)**	**1.19 (-11.97)**
Inhibition: response selection RT cost[g] (Z-score)	1.76 (-0.82)	**4.21 (-4.21)**	**3.79 (-4.10)**	0.7 (0.86)
Inhibition: response selection accuracy[g] cost (Z-score)	**0.5 (-3.62)**	**1.5 (-11.90)**	-0.81 (7.22)	0.25 (-1.55)
Flexibility: Letter/Number alternation RT cost[g] (Z-score)	**29.2 (-2.71)**	**49.65 (-6.15)**	**-16 (4.91)**	11.85 (0.21)
Flexibility: Letter/Number alternation Accuracy cost[g] (Z-score)	**5.5 (-13.5)**	**6 (-14.73)**	**10.5 (-25.89)**	-0.5 (1.40)
Flexibility: TMT-Part B minus A– speed[h] (Percentile)	69 s. (P5-10)	96 s. (P25-50)	**222 s. (<P5)**	13 s. (P90-95)
Flexibility: TMT-Part B minus A – accuracy[h] (Percentile)	**10 errors (<P5)**	2 errors (P10-15)	**6 errors (<P5)**	1 error (P5-10)
Flexibility: FAS fluency – number of words[b] (1 minute each letter)	46 (P50-60)	21 (P30-40)	**13 (<P10)**	56 (P80-90)
Rule detection: Brixton – accuracy[i] (scaled score)	**26 errors (2)**	**27 errors (2)**	20 errors (5)	**-[j] (2)**

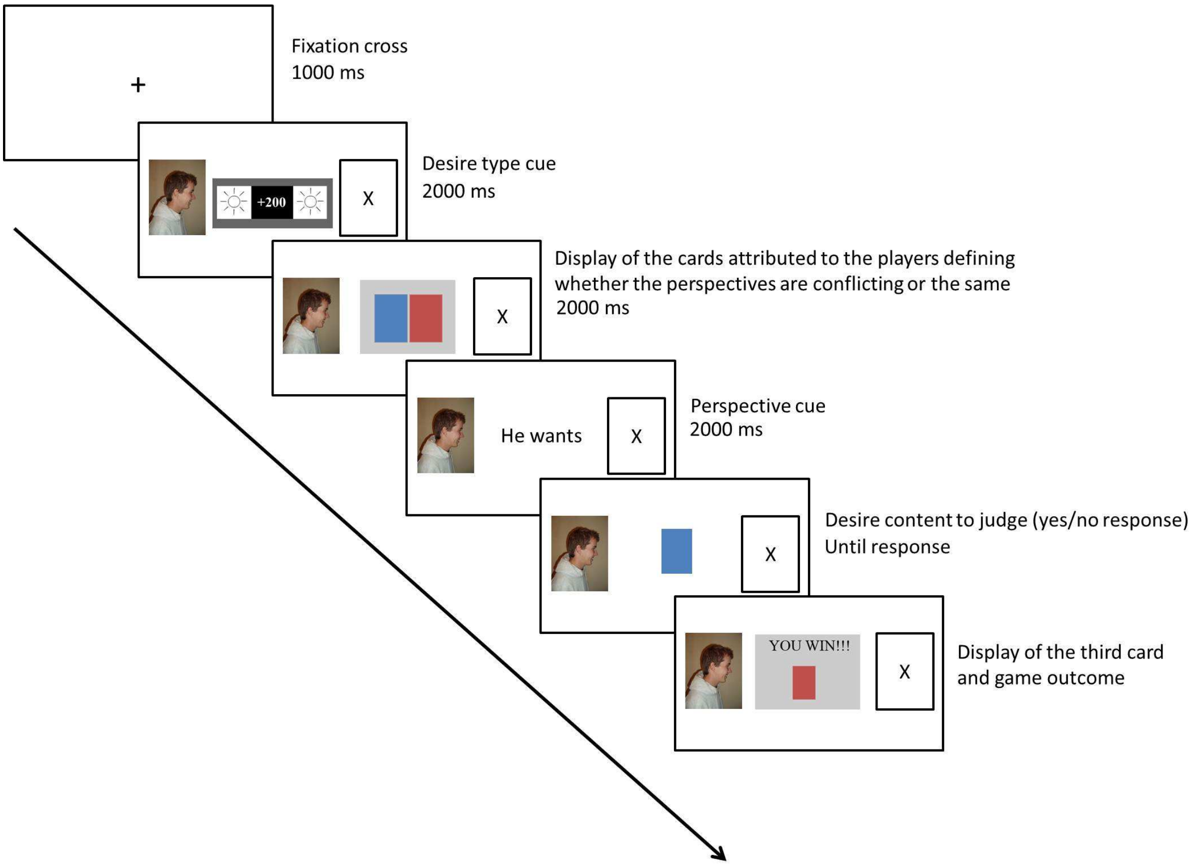
In bold: performance considered as impaired compared to controls. NT: not tested

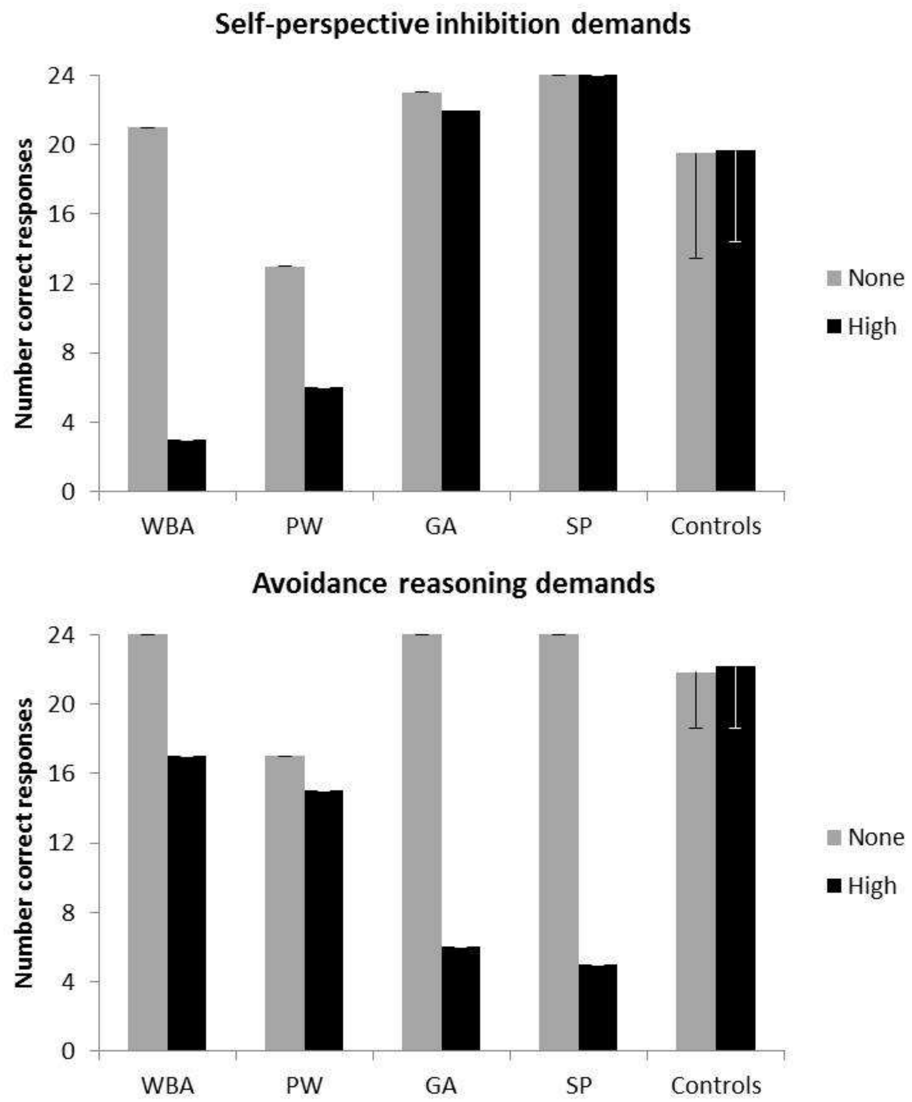
[a] Birmingham Cognitive Screen (Humphreys et al., 2012). Fourteen pictures to name.
[b] Norms from Tombaugh et al. (1999).
[c] Unpublished battery of working memory tasks with norms on 16 control subjects aged 46-68. Includes a classic digit span, the recall of digit in ascending order (manipulation), the recall of digits after an interference task and the recall of the last 4 or 3 digits of a string of digits (updating).
[d] Birmingham Cognitive Screen (Humphreys et al., 2012). Story with 15 target items to remember.
[e] Warrington Recognition Memory (Warrington, 1984).
[f] D2 Test (Brickenkamp, 1966). Norms are not available for individuals > 60 years. The test was thus not administrated to PW.
[g] Unpublished battery of inhibition and flexibility tasks with norms on 16 control subjects aged 46-68. Includes a cancellation task with salient distractors (stimulus selection), a stimulus-response remapping task (response selection) and the alternated cancellation of the letter and the number within pairs of items. The cost is calculated by subtracting the baseline from the executive control condition.
[h] Trail Making Test (Reitan, 1958). Norms from Godefroi et al. (2008).
[i] The Hayling and Brixton Tests (Burgess and Shallice, 1997)
[j] Raw score not available anymore


Z=-16
Z=-8
Z=0
Z=8
Z=16
Z=24
Z=32
Z=40

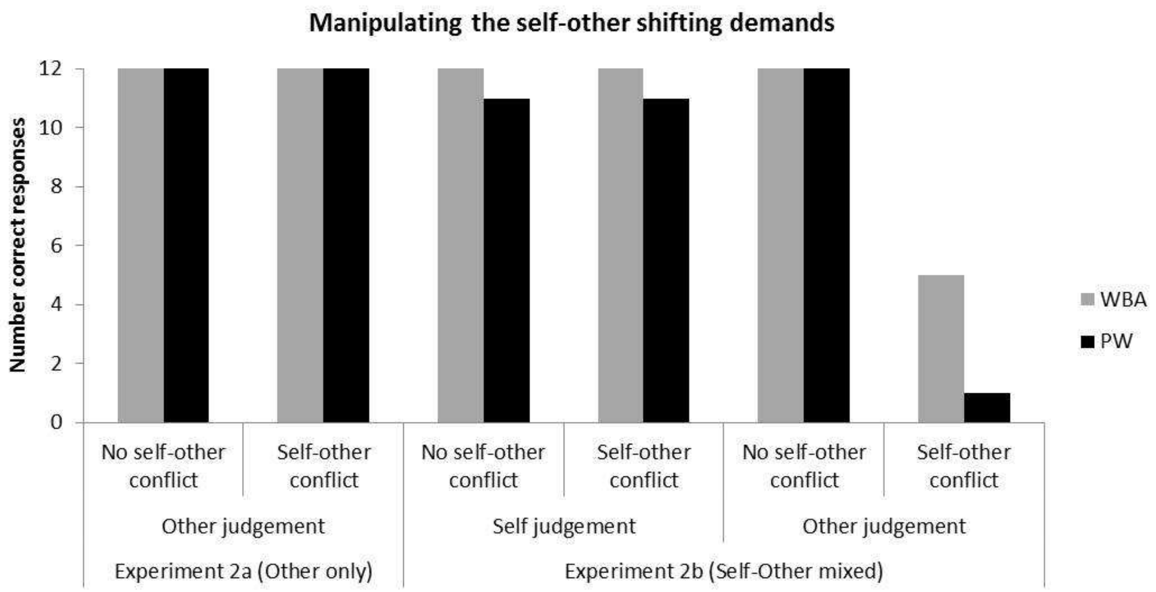


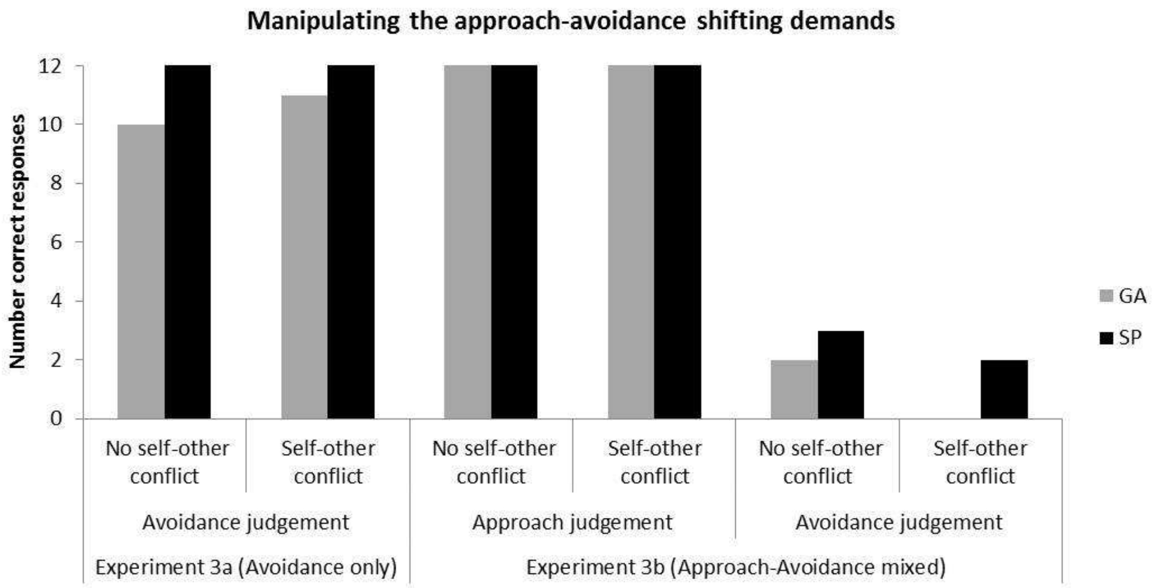
Approach-desire
+200
Avoidance-desire
-200
Matching prompt (yes response)
Mismatching prompt (no response)
Matching prompt (yes response)
Mismatching prompt (no response)
Conflicting perspectives:
Participant's card
Opponent's card
Other-perspective taking: HE wants?
Self-perspective taking: YOU want?
Same perspectives:
Participant's card
Opponent's card
Other-perspective taking: HE wants?
Self-perspective taking: YOU want?

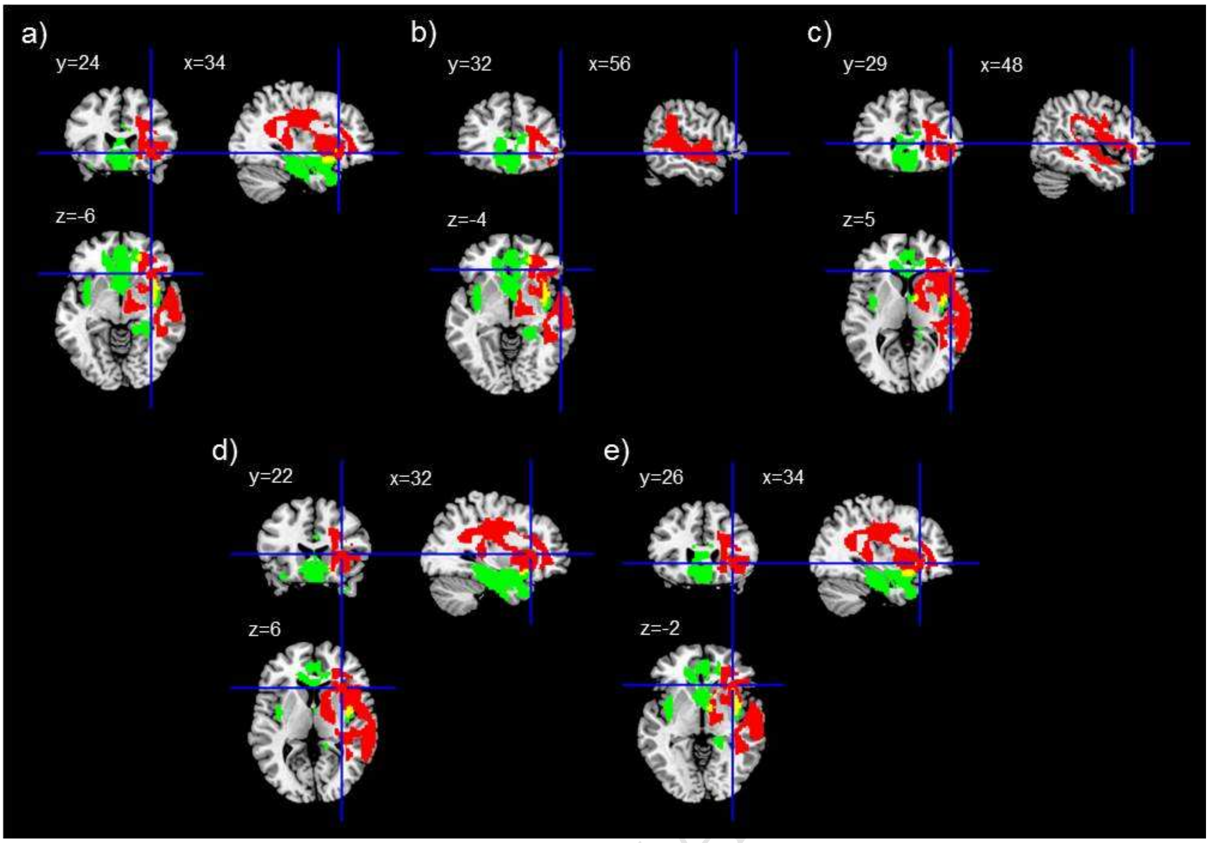

+
Fixation cross
1000 ms
+200
X
Desire type cue
2000 ms
X
Display of the cards attributed to the players defining whether the perspectives are conflicting or the same
2000 ms
He wants
X
Perspective cue
2000 ms
X
Desire content to judge (yes/no response)
Until response
YOU WIN!!!
X
Display of the third card
and game outcome


Self-perspective inhibition demands
Number correct responses
24
20
16
12
8
4
0
WBA
PW
GA
SP
Controls
None
High
Avoidance reasoning demands
Number correct responses
24
20
16
12
8
4
0
WBA
PW
GA
SP
Controls
None
High


SCORE BOARD
Simon
GS
00.00
00.00
BLAME
IT ON
THE
WEATHER
+150
BANK


Manipulating the self-other shifting demands
Number correct responses
12
10
8
6
4
2
0
No self-other conflict
Self-other conflict
No self-other conflict
Self-other conflict
No self-other conflict
Self-other conflict
Other judgement
Self judgement
Other judgement
Experiment 2a (Other only)
Experiment 2b (Self-Other mixed)
WBA
PW


Manipulating the approach-avoidance shifting demands
Number correct responses
12
10
8
6
4
2
0
No self-other conflict
Self-other conflict
No self-other conflict
Self-other conflict
No self-other conflict
Self-other conflict
Avoidance judgement
Approach judgement
Avoidance judgement
Experiment 3a (Avoidance only)
Experiment 3b (Approach-Avoidance mixed)
GA
SP


a)
y=24
x=34
z=-6
b)
y=32
x=56
z=-4
c)
y=29
x=48
z=5
d)
y=22
x=32
z=6
e)
y=26
x=34
z=-2